EFFECTS OF ADDITION OF TORULA YEAST SINGLE CELL PROTEIN ON SENSORY AND NUTRIENT QUALITIES OF A FRIED POTATO PRODUCT

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EFFECTS OF ADDITION OF TORULA YEAST SINGLE

CELL PROTEIN ON SENSORY AND NUTRIENT

QUALITY OF A FRIED

POTATO PRODUCT

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CHAPTER I

INTRODUCTION

The awareness of a global protein shortage in the 1930's and 40's stimulated scientists to look for new, inexpensive protein sources which could be used to fill this protein gap. The validity of an actual protein shortage is questionable when you look at total world food production in relation to the total population. What is sure is that there is inequality in the distribution of foodstuffs leaving one segment of the world's population without the quantity and quality of food needed for a healthy life. The reason for this inequality is not solely the lack of agricultural production in these parts of the world, but also involves political, socioeconomic, and cultural factors. The solution, then, must involve action in all of these areas with provision of high quality inexpensive protein being only one aspect.

The search for new protein sources turned researchers' attention to micro-organisms or single cell protein (SCP). SCP has a high concentration of good quality protein, and characteristics which give it potential as a food source. With SCP there is the possibility of producing large quantities of protein without the use of agricultural land. It has a rapid growth rate and can be grown on many readily available substrates including sulfite waste from pulp and paper manufacturing, molasses, whey, and other industrial products (Edozien, 1969).

How to utilize this potentially vast protein source is the question that must be answered. It is not enough to have a food which contains desirable nutrients. People buy food, not nutrients. If SCP cannot be put in a form which people will accept, it will be no good to anyone. Taste, appearance, eating habits, and economics are the bases on which people buy food. Nutrient addition to food must be done in such a way that least disturbs these (Sebrell, 1969). This then is the challenge to food scientists and technologists, to put SCP in a form which is highly edible and well accepted by the populations most in need of its nutritional benefits.

Nature of the Problem

Research on SCP intensified in the early 1970's. A failure of Chile's anchovita harvest, high soya bean prices, and an increase in the value of meat and vegetable protein made the production of SCP for human and animal consumption economically feasible (Annonymous, 1974).

Food and agriculture industries which produce waste products that are potential substrates for SCP saw that SCP production could help them in two ways. With the new market for SCP in animal feeds, producing a saleable product from a waste product could make them a profit. The added benefit of having SCP consume their waste would help solve the disposal problem which would otherwise cause environmental pollution. The major impetus which began indepth research into SCP production then was not great humanitarian ideals; rather, it was economic prudence.

SCP production methods have improved greatly in an attempt to make them as economical as possible (Annonymous, 1974). Concurrent with this development has been research on a potential human food market for SCP.

The animal feed industry is highly competitive and depends on the fluctuating costs of traditional feed protein concentrates. SCP could be a new source of animal feed protein concentrates. The developing potential for such mass production of SCP necessitates that there be a stable market for it before large capital is invested in production. Finding human food uses for SCP will be one way to provide this market and is critical if funding for SCP research and development is to continue. Scrimshaw and Altuschul (1969) predict that as the technology made it possible to produce low-cost forms of soybean protein concentrate with functional properties enabling it to be used in numerous foods, so the same will happen with SCP. This encouraging outlook for the future of SCP is good news to those in the business of SCP production as well as those who see SCP playing a role in alleviating nutritional deficiency for the needy populations of the world. Single cell protein can be bacteria, yeast, fungi, or algae. To date, yeasts appear to have the most promise as a potential food for human consumption (Spicer, 1970). One of the major uses of yeast in food at the present time is for fortification of foods low in protein or those foods whose protein amino acid profile is lacking in an amino acid which is contained in the yeast at significant levels. Improving the amino acid profile of a food increases the protein efficiency ratio (PER) of the food as demonstrated when torula yeast was added to wheat at various levels (Bressani, 1968). This increase in PER is due to the complementary effect that yeast, being high in the amino acid lysine, has on wheat, which is low in lysine (Waslien, Calloway, and Margen, 1968). Yeast is also high in the B vitamins thiamin, niacin, and riboflavin; and it can be added to foods to increase the protein content of these as well (Scott and Sanderson, 1972). The Council on Food and Nutrition of the American Medical Association and the Food and Nutrition Board published a joint policy paper on the addition of vitamins, minerals, and synthetic nutrients to foods (Sebrell, 1969). The requirements they set down were that there should be good evidence that the food being supplemented must be physiologically and/or economically advantageous for a large segment of the population and be an effective means of distributing the needed nutrient. The foods targeted for fortification must be widely accepted by the general populous and low in cost. The fortification should not be detrimental to the flavor or appearance of the product. Research done on fortification of foods with yeast SCP should meet these same requirements.

The potato has a very low protein content, especially with the skin removed. Potato products of all kinds, from mashed potatoes to french fries, are popular in this country and are eaten by almost every segment of our society. Any population in need of nutrient supplementation (low income persons, children, and reservation Indians, for example) could benefit from fortification of this well-accepted, low-cost food item. Torula yeast is a bland-flavored yeast high in protein, the amino acid lysine, and the B vitamins and could be used as the nutrient supplement (Klapka, Duby, and Paucek, 1958).

Purpose and Objectives

The purpose of the research was to develop a highly acceptable fried potato product containing torula yeast for nutrient fortification.

The objectives of the study were as follows:

1. To develop an acceptable fried potato product in which to incorporate torula yeast.
2. To determine the highest level of yeast acceptable in this product.
3. To compare the nutrient content of the fried potato product with and without yeast.
4. To determine the fat absorption of the potato product upon frying with and without torula yeast added.

Hypotheses

The following hypotheses were postulated for this research:

H1: For each of the following sensory characteristics there is no significant difference between mean response values due to interaction between yeast levels and water levels. The sensory characteristics evaluated are: moisture, crispness, denseness, oiliness, saltiness, bitterness, uncooked potato flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability.

H2: For each of the following sensory characteristics there are no significant differences between mean response values given for the potato products made with the various yeast levels. Sensory characteristics evaluated are: moisture, crispness, denseness, oiliness, saltiness, bitterness, uncooked potato flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability.

H3: For each of the following sensory characteristics there are no significant differences between mean response values given for the potato products made with the various water levels. Sensory characteristics evaluated will include: moisture, crispness, denseness, oiliness, saltiness, bitterness, uncooked potato flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability.

H4: There are no significant differences in mean oil absorption between products made with the various yeast and water levels upon frying due to interaction between yeast/water levels.

H5: There are no significant differences in mean oil absorption between products made with the various yeast levels upon frying.

H6: There are no significant differences in mean oil absorption between products made with the various water levels upon frying.

H7: There are no differences in nutrient content between potato products made with and without torula yeast.

Assumptions and Limitations

The following assumptions were made for this study:

1. The sensory evaluation panel represents the general population.
2. The sensory evaluation panel will evaluate the product as instructed.
3. The nutrient composition values in the nutrient tables are equivalent to the nutrient values in the products used in making the potato products.

4. The experiments will be conducted under controlled environmental conditions.

Limitations for this study were identified as follows:

1. Only four levels of yeast substitutions will be tested.
    a. 5 per cent substitution
    b. 7.5 per cent substitution
    c. 10 per cent substitution
    d. 12.5 per cent substitution
2. Only four levels of water will be tested:
    a. 75 ml/38 g dry ingredients
    b. 85 ml/38 g dry ingredients
    c. 95 ml/38 g dry ingredients
    d. 105 ml/38 g dry ingredients
3. Nutrient analysis will be calculated using published nutrient values for the foodstuffs used in making the potato product.
4. Product production is on a pilot scale, which may not simulate production on a larger scale.

Definition of Terms

The following are the definitions of terms used in this study:

Single Cell Protein. Dried cells of micro-organisms (bacteria, yeast, actinomycetes, molds, higher fungi, or algae) grown in large-scale culture systems for use as protein sources in human foods or animal feeds (Litchfield, 1983).

Fortification. Addition of nutrients to food at levels regarded as desirable and may bear no reference to "natural" level in the product (Sebrell, 1969).

Protein Concentrate. Product containing 50 per cent or more of the dry matter as crude protein (Tannenbaum, 1969).

Protein Isolate. Product containing 90 to 98 per cent or more of the dry matter as crude protein (Tannenbaum, 1969).

Biological Value. A measure of the proportion of the absorbed nitrogen retained by the animal body for growth and maintenance (Chen and Peppler, 1978).

Protein Efficiency Ratio. The amount of weight gain in a growing animal per unit weight of protein intake as compared with that observed for casein (Chen and Peppler, 1978).

Net Protein Utilization. A measure of the proportion of the total nitrogen intake retained by the animal body for growth and maintenance (Chen and Peppler, 1978).

Sensory Evaluation. A scientific discipline used to evoke, measure, analyze, and interpret reactions to those characteristics of foods and materials as they are perceived by the senses or sight, taste, touch, and hearing (Prell, 1976).

Format of Thesis

The experiment described in Chapter III was organized and prepared as an individual manuscript for publication in the most acceptable journal. The experiment was written according to the Style Guide for Research Papers, Institute of Food Technologists and the Journal of Food Science. References cited in Chapter III will also be cited in the Selected Bibliography section.

CHAPTER II

REVIEW OF LITERATURE

This study evaluated the sensory and nutrient effects of the addition of torula yeast single cell protein (SCP) to a fried potato product. Sensory evaluation and nutrient calculation were used to evaluate these effects. This review covers a brief history of single cell protein research, the production and processing of yeast as SCP, and yeast's effectiveness and acceptability in nutrient fortification in human foods. The potato may be an appropriate medium for incorporation of yeast SCP. The extent of production and consumption of potato products in this country is discussed, and some methodologies of frozen potato product production are also described. The use of sensory evaluation in product development is also discussed.

General History of SCP

The mass production of SCP for human feeding dates back to World War I when German soldiers were fed yeast, especially Candida utilis, as a protein supplement. Regulation of SCP production and distribution and investigation of its technological and economic feasibility has been going on since that time. The first single cell protein conference was held in 1967 at Massachusetts Insitutie of Technology. The conference emphasized the technical feasibility of SCP and the need for increased knowledge of acceptability, safety, and nutritional aspects of various types of micro-organisms as human food (Humphrey, 1975).

The development of pilot and full-scale plants by various companies proved the technical feasibility of SCP production. The nutritional value and safety of SCP in human consumption was, and continues to be, evaluated by the Protein Advisory Group (PAG) of the United Nations system. A statement by PAG on microbial protein for human consumption concluded that

> . . . there was adequate evidence to indicate that certain species of yeast, algae, and bacteria could be useful sources of protein, as well as of vitamins and minerals for both animal and human feeding.

It emphasized, however,

> . . . that the safety and human acceptability of such materials could depend on the organisms selected, on the nature and quality of the substrate utilized, on the conditions of growth, and on the specific details of the processing and handling of the material (Scrimshaw, 1975).

SCP Organisms For Human Consumption

SCP organisms can be algae and photosynthetic bacteria, nonphotosynthetic bacteria, filamentous fungi, and yeasts. All have attributes that make them appealing for mass production as human and animal feeds. Algae and photosynthetic bacteria do not require an organic carbon substrate due to their photosynthetic ability. Nonphotosynthetic bacteria have a rapid growth rate, metabolic versatility, and high protein content. Filamentous fungi have cellulolytic and ligninolytic activity allowing them to grow on lignocellulosic wastes; and yeasts have a rapid growth rate, adaptability to a variety of substrates, and a high protein content (Tuse, 1983).

An analysis of the various SCP types points to yeast as the likely candidate for human nutrition (Calloway, 1974). Bacteria have variable protein content and digestibility; and human subjects fed bacterial SCP in high doses experienced vertigo, nausea, vomiting, and diarrhea. The algae have low digestibility and variable production rates. The typical slow growth rate of fungi makes their adaptibility to commercial production economically restrictive.

Yeasts, with their high digestibility (87 to 90 per cent) and relatively high biological value (70 per cent), are the SCP source with the most promise for human consumption. A comparison of the extent of production of the various microbial types gives evidence of this. Moo-Young (1976) reported that 1.4 million tons of yeast were produced per year compared to 2,000 tons of bacteria and 20,000 tons of Chorella. No mycelial fungi were being produced on a commercial scale at that time. One particular species, Candida utilis (torula), has had fairly good acceptance, producing relatively few pathophysiological reactions.

Three types of yeast have been approved for human food use in the United States by the Food and Drug Administation. These are S. cerevisiae (bakers' yeast), C. utilis (torula yeast), and K. fragilis (fragilis yeast). A bakers' yeast protein concentate has also been approved for human food use (Litchfield, 1983).

Substrates For SCP Growth

There are many substrates which can be used for SCP production. These include, but are not restricted to, petroleum products, natural gas, waste from industrial processing plants (sulfite waste liquor, etc.), and waste from food processing plants (whey, molasses, etc.). There has been general acceptance of the concept of micro-organisms as human food when grown on carbohydrate substrates such as whey, starches, sugars, and lignocellulosic materials. Currently, in fact, most commercial yeast is produced on either molasses or sulfite liquor (Tuse, 1983). The hydrocarbon-grown micro-organisms have experienced great difficulty in getting acceptance, however, due to the concern about carcinogenic residues which might be present in products grown on hydrocarbons (Chen and Peppler, 1978).

Studies on the Use of Yeast SCP For Human Consumption

Nucleic Acid Content of Yeast SCP

Hyperuricemia and the associated problems of gout, renal stones, and hyperuricemic nephropathy may be caused by increased production or lack of excretion of uric acid. The dietary intake of foods high in nucleic acids, protein, and fat has been associated with an elevation of blood uric acid levels. A study of six commercial yeast products (composed of either *S. cerevisiae* or *C. utilis* grown on various substrates) showed nucleic acid contents of 8.1 to 11.5 per cent (Sarwar, Shah, Mangeau, and Hoppner, 1985). Litchfield (1983) reported nucleic acid contents ranging from 5 to 15 per cent depending on the yeast species and the substrate.

A plasma uric acid level of 7.0 g per 100 ml is considered the highest safe level for the normal United States male. Edozien (1969) found a linear increase in serum uric acid levels in male subjects fed up to 90 g torula yeast per day. There was approximately a 2.5 g per

100 ml increase for each increase of 45 g of yeast. When fed 45 g yeast per day, less than 10 per cent of the subjects maintained plasma uric acid levels below 7.0 g per 100 ml. Based on these and other similar results, PAG recommended that the limit of intake of nucleic acids from single cell protein be two g per day (PAG, 1975). This would be equivalent to ingesting from 13 to 40 g of intact yeast cells per day, depending on the type of yeast and substate. An intake restricted to this level would provide less than one-third the Recommended Dietary Allowance for protein.

If yeast is to serve as the primary source of protein in the diet, the nucleic acids must be reduced in order to stay within the PAG recommendation. There are several ways of doing this. Yeasts can be genetically selected for varieties with high protein to nucleic acid ratios, grown on substates that reduce the nucleic acid content, and/or processed to remove a portion of the nucleic acid (Edozien, 1969). Until the technology develops to carry out these methods economically, yeasts must be added to human foods at levels that do not exceed the suggested limit.

Nutritional Value of Yeast SCP

Yeast SCP has a high content of protein and the B vitamins niacin, thiamin, and riboflavin. Sarwar, Shah, Mongeau, and Hopper (1985) showed a true protein (not including non-protein nitrogen) content of 32.6 to 43.6 per cent in six commercial yeast products. All of these had high levels of threonine and lysine and low levels of the sulfur-containing amino acids and tryptophan. The deficiency of these essential amino acids makes the biological value (BV) and net protein utilization of yeast products comparable to vegetable proteins but much lower than animal proteins.

Although yeast is deficient in some of the essential amino acids, it is high in overall protein content and lysine content. This makes its use as a protein supplement possible. Complementation of cereal proteins, which are low in lysine, with dried yeast improves the BV and protein efficiency ratio (PER) of both. Sure (1948) showed this by feeding rats diets of either wheat flour (low in lysine) or corn flour (low in lysine and tryptophan) which had been supplemented with various levels of yeast or with lysine and tryptophan. Results showed that rats fed wheat flour diets supplemented with either yeast or the individual amino acids had greater weight gains and protein efficiency than rats fed unsupplemented diets for both the wheat and corn fed rats. Also, yeast levels supplying lower levels of lysine and tryptophan provided similar growth rates to the amino acid supplemented diets. This suggests that the incidental addition of other nutrients in the yeast contributed to the greater growth.

Seeley, Ziegler, and Summer (1950) found that dried brewers' yeast was a better supplement than nonfat milk solids. Weanling rats fed wheat bread supplemented with one per cent dried yeast or three per cent nonfat milk solids had similar increases in growth rate over the control diet when this was the only source of food. Again, the addition of other factors, such as the B vitamins, with the addition of yeast SCP may be the reason for its greater effect on growth rates.

The improvement of the PER of rice, cottonseed, and sesame by supplementation with torula yeast has also been reported (Bressani, 1968). These studies demonstrate the potential for yeast as an effective complementary protein. The incidental addition of their nutrients found in the yeast may have added benefits as well.

Food Applications of Yeast SCP

Yeast SCP has many applications in human foods. It may be used either in the form of whole cells or as an isolated protein concentrate. As an isolated protein concentrate, yeast proteins can be added to foods for the beneficial functional properties. The protein concentrate has long been used as a flavor enhancer, and its fiber-forming property, whipping property, foaming property, wettability, solubility, and emulsion capacity give it applications in texture improvement (Chen and Peppler, 1978). Okezie and Kosikowski (1981) found that isolated protein concentrate from *C. tropicalis* and *C. utilis* had functional properties of wettability, emulsion capacity, and whippability that were equivalent or better to those found in soy protein concentrate. They suggested that such properties could be utilized in the manufacture of confections, whipped toppings, frozen desserts, meat, and as an egg white substitute.

Torutein, a protein concentrate derived from torula yeast and manufactured by the Amoco Corporation, was added to cereals, tortillas, doughnuts, cakes, batters, and meat patties with good results (Schnell, Akin, and Flannery, 1967). They added Torutein at levels between one and nine per cent to these products, and when added as a 50 per cent substitution for the dried egg yolk to cake doughnuts, no loss in bake quality and flavor resulted. A similar substitution for the dried egg yolk in yellow cake mixes gave a cake of greater volume, sweeter taste, and a more moist texture.

Despite these functional properties of the isolated yeast protein concentrate, the whole yeast cell appears to be the easiest and most economical form in which to utilize the organism. In the form of whole cells, yeast has been used for the improvement of the quality of protein in foods. Incaparina, a weaning food developed at the Institute of Nutrition of Central America and Panama, is fortified with three per cent dried torula yeast. Torula yeast has also been added to rye bread at levels up to five per cent. Whole yeast cells have been added to macaroni for the purpose of enrichment of the vitamin and mineral content and to other foods as a general dietary supplement. The physical properties of pizza dough and of processed meats have been improved by the addition of whole yeast cells (Chen and Peppler, 1978).

Effects of Addition of Yeast SCP on Sensory Acceptability of Foods

The success of using dried, largely intact yeast cells as a component of human food depends on the effects on the foods to which it is added. Research indicates that yeast SCP can be added to foods at levels which improve their nutrient content while still maintaining sensory acceptability.

Scott and Sanderson (1972) compared five yeasts for effects on acceptability of a cereal wafer. Acceptability decreased linearly with the increased addition of all of the yeasts. Brewers' yeast or torula yeast could be incorporated at the highest level (19 per cent yeast substitution) while still maintaining an acceptable rating. This level of yeast provided eight per cent protein from yeast in the wafers. Klapka, Duby, and Paucek (1958) did a study on the sensory acceptability and physiological effects of torula yeast in the diets of patients in a mental hospital and showed that there were no adverse physical reactions (nausea, allergy, or vomiting) with an average consumption of 10 g of yeast per day. The SCP was found to be highly acceptable in soups, meatloaves, casseroles, gravies, tomato sauces, and mashed potatoes. In general, it was not well accepted in salads and cottage cheese, but could be put in meat dishes and cereals at fairly high amounts.

Kamel and Kramer (1978) found that yeast could be incorporated in levels up to 7.5 per cent of the flour in date bars. This level increased the protein content of the bars from 3 to 10 per cent and had no negative effects on the sensory quality or acceptability of the product.

Provesteen-T Yeast Product

Provesteen-T is a dried torula yeast product grown on a sucrose feedstock and produced by a single cell protein production process patented by the Phillips Petroleum Company. The process could be used to produce virtually any form of SCP on a variety of feedstocks; however, sugars such as glucose and sucrose are the feedstock for the torula in Provesteen-T (Phillips, 1984).

A diagram of the process is given in Figure 1. The fermentor is innoculated with the yeast culture at the onset of the process. The substrate on which the yeast culture will feed is composed of a carbon source, growth nutrients, oxygen, and water. The yeast cells are grown at a density of over 13 per cent total solids, which is quite dense compared to the three to four per cent total solids in conventional processes. The feedstock is continuously dripped into the fermentor in small amounts so that it is instantly utilized by the dense yeast culture in this ultra-high cell density process. All of the nutrients produced during fermentation remain in the final product since the yeast cells are continually drawn off of the fermentor and are taken directly to the pasteurizer and drier. The costly process of concentrating the product and disposing of the effluent are eliminated in this way.

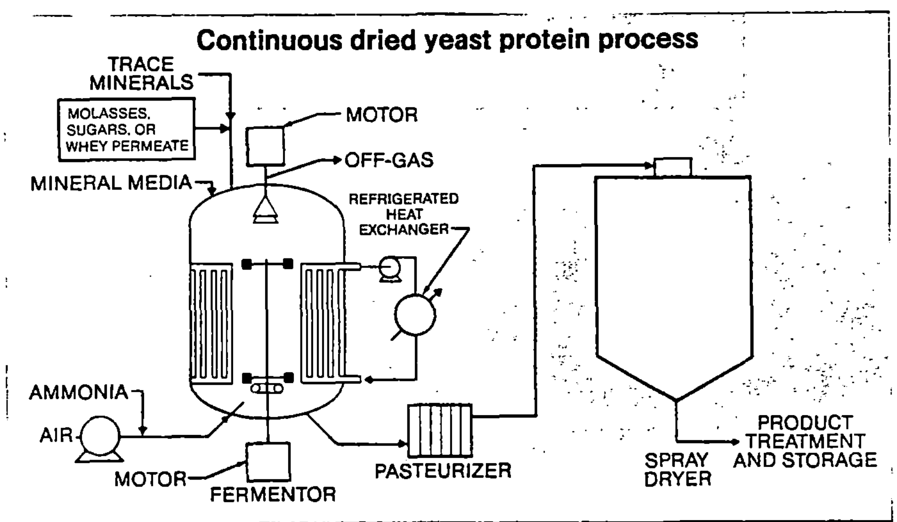

Figure 1. Phillips' SCP Fermentation Process

These advances made in this new process help to decrease the cost of production. The cost with this process is between $.70 and $1.50 per pound with 30 to 50 per cent of the cost being the feedstock. The 1500 liter pilot plant fermentor currently in use can produce up to 75 tons of SCP a year (Klausner, 1984). Nutrient composition of the Provesteen-T is given in Appendix A.

Potato Products

The potato is grown commercially in every state in the United States; but, Idaho, Washington, Oregon, Maine, Minnesota, and North Dakota are the primary potato producing states. The annual per capita consumption of potatoes and potato products has risen from 103 pounds in 1956 to 122 pounds in 1977. This rise in consumption is almost entirely due to an increase in the use of processed potato products (Annonymous, 1980).

The composition of total processed potato product volume in 1975 was: 22 per cent chips, 22 per cent dehydrated potato, 53 per cent frozen potato products, and 3 per cent other (Smith, 1977). The processing of frozen and dehydrated potato products is increasing rapidly with per capita consumption of frozen potato products increasing from 7 pounds in 1960 to 40 pounds in 1977 (Annonymous, 1980). Frozen potato products account for 55 per cent of all frozen vegetables, and french fries make up 90 per cent of the total frozen potato products produced (Smith, 1977).

The increase in consumption of frozen french fries is mainly due to an increase in institutional and food service use, which accounted for 75 per cent or more of the yearly production of frozen french fries in 1975. Retail outlets accounted for 70 per cent of production of frozen potato products other than french fries (Talburt and Smith, 1975).

This increasing consumption of potato products by our society indicates their increasing role as a component of our diet. As such, interest in their contribution to the nutritional status of our population has been renewed.

Sensory Evaluation

Sensory evaluation is a tool used in the food industry as a guide in the selection of new product targets, product development, and quality control. Sensory evaluation of products in the research and development phase can reduce financial losses due to failure of market acceptance.

Types of sensory evaluation can be divided according to the task of the respondent. There are three categories under the task of the respondent. These are the discrimination tests, which measure differences between samples; the descriptive tests, which can be qualitative or quantitative and give a description of the sensory attributes of a sample; and affective tests, which measure how well a stimulus is liked.

Type of subject can be either untrained consumers, highly trained experts, or semi-trained laboratory panels. There are three major location possibilities for testing: the laboratory, where conditions may be highly controlled; a central location such as a community facility, which allows for less controlled conditions; and in-house, which allows for extremely limited control. Combinations of task, respondent, and location parameters must be made that create a testing situation that is best suited for providing the information desired (Schutz, 1979).

Considerations in Testing

Depending on the type of sensory evaluation employed, various degrees of control are put on the environment, the samples being tested, and the panelists doing the evaluation. Greatest control can be exerted in tests run in the laboratory.

Environmental conditions should be such that there is the least distraction to the panelist during testing. The sample preparation area should be separate from the testing area to control distractions and odors, and the testing area should be arranged so that the least interaction between panelists occurs (via dividers, booths, etc.). Lighting should be adequate, and special lighting can be used to prohibit distinction of sample color, if necessary.

Samples presented to the panelists should all be prepared in the same way. They should be representative samples of the product and should be served in the same quantity and at the same temperature each time. Coding should be done in such a way as to not cause bias in the panelists, and sample presentation should be random to avoid any positional bias. Consideration should also be given to the number of samples that can be effectively evaluated in each session (Larmond, 1977).

Selection and Training of Panelists

Selection and training of panelists depends on the type of sensory testing done. Panelists should be available for the entire testing period, be willing and motivated to serve, and not dislike the food. For discrimination and descriptive testing, the ability to identify the four basic tastes, sweet, sour, bitter, and salty, is a minimum requirement. The ability to recognize duplicate samples and samples of the actual product to be tested can also be used as criteria for selection. Panelists for affective testing should be a representative sample of the target population. Training is given panelists for discriminative and descriptive testing to develop a common understanding and terminology and to fine tune their sensory abilities (Campbell, Penfield, and Griswold, 1979).

Types of Tests

There are several types of tests which can be used in sensory evaluation. The type used depends on the information desired. Discrimination tests are used to determine differences between samples. Commonly used discrimination tests are the paired comparison, triangle, duo-trio, and taste threshold tests. These tests indicate presence and direction of differences but do not reveal the magnitude of differences.

Descriptive tests compare characteristics of samples and show magnitude of differences. They include ranking tests, scoring tests, flavor and texture properties, quantitative descriptive analysis, and magnitude estimation. Descriptive tests provide much more information about individual characteristics of samples and degrees of difference between samples than do discrimination tests.

Affective tests include tests to determine consumer acceptance of a product and tests to determine consumer preference for a product. The hedonic scale, which expresses degrees of like and dislike, is commonly used with these tests. Little is required of panelists in affective testing since all that is resired are statements of like or dislike.

Different levels of panelist training are required with the different tests. In general, descriptive tests require the most extensive training since panelists may be asked to provide detailed information about sensory qualities of the foods tested. Discriminative tests do not require quite as much training, but basic abilities in distinguishing flavors, textures, odors, and colors are necessary. Affective testing requires no training; all that is generally asked for are degrees of like or dislike for a product.

Interpretation of Data

The purpose of sensory evaluation is to gather subjective information for use in drawing conclusions about the product being tested. In some cases, conclusions may be obvious after simple averaging and tabulating of the data. More often the inherent variability of responses between judges, and for the individual judge on repeated ratings, makes it necessary to use statistical procedures to determine differences in sample data that are due to intended responses and those which are due to chance.

Statistical analysis of experimental data takes into account the limitations of the various tests being used. For example, the triangle test, which requires the panelists to identify the odd sample from a set of three samples, is analysed based on the probability that if there is no difference between samples the odd sample will be chosen by chance 33.5 per cent of the time (Larmond, 1977). Researchers must plan experiments so that mathematical models appropriate to their testing procedures can be used, and the desired information can be drawn from their data. A typical procedure used in analysis of sensory data is the analysis of variance which is used to determine significant differences among means. Relationships between variables and between sensory and objective data can also be determined.

CHAPTER III

EFFECTS OF DRIED TORULA YEAST ON SENSORY AND NUTRIENT QUALITIES OF A FRIED POTATO PRODUCT

Introduction

The awareness of a global protein shortage in the 1930's and 40's stimulated scientists to look for new, inexpensive protein sources which could be used to fill this protein gap. The search focused attention on protein obtained from micro-organisms (single cell protein, or SCP). The high protein, vitamin, and mineral content of SCP, as well as its lack of dependence on agricultural land and appropriate weather conditions for production created great interest in micro-organisms as a reliable protein source for the world's expanding population.

There are 4 types of SCP: bacteria, yeasts, fungi, and algae. Yeast appears to be the most promising of the 4 in terms of its potential for use in foods for human consumption (Spicer, 1970). Yeasts outproduce the other SCP types on a tonnage basis (Moo-Young, 1976). In addition, they are an excellent source of the B vitamins and have a high concentration of protein. Yeasts are high in lysine, an amino acid often low in staple cereal crops. The species S. cerevisiae, C. utilis, and K. fragilis can be produced on carbohydrate-containing substrates and are approved for human consumption (Chen and Peppler, 1978).

The nutritive value of yeast protein has been thoroughly investigated. The protein efficiency ratio (PER) of wheat flour increased from 0.82 to 2.31 when supplemented with 10% C. utilis (Jarquin, Noriega, and Bressani, 1966). Similar results were found when rice, corn, cottonseed, and sesame were supplemented with C. utilis (Bressani, 1968). This increase in PER is apparently due to the lysine and tryptophan contribution made by the yeast (Sure, 1948). The addition of dried yeast to white bread at 1 and 3% of the flour caused an increase in daily weight gain of weanling rats over that of rats fed white bread without SCP. This increase in daily weight gain was greater than the increase seen when nonfat dry milk was added to the white bread at 1 and 3%. Inclusion of dried yeast did not improve the biological value of the white bread, so the increased growth rates were most likely due to the increased overall protein content and B vitamin content resulting from dried yeast addition (Seeley, Ziegler, and Summer, 1950).

Yeast SCP can have positive effects on the nutritional value of various staple food items, especially cereal grains and vegetables. This fact is not enough, however. People buy food, not nutrients, so yeast must be in an appealing and edible form if it is to be of any benefit. Five yeasts were tested for acceptability in cereal wafers at increasing levels. Wafers made with the 5 different yeasts decreased in acceptability with increasing levels of any of the yeasts used, but torula (C. utilis) and brewers' yeast, even at the highest level tested, still maintained an acceptable rating (Scott and Sanderson, 1972). Torutein, a protein concentrate derived from torula yeast, has been added to cereals, tortillas, doughnuts, cakes, and meat patties with good results (Schnell, Akin, and Flannery, 1976). Torula yeast has been added up to levels of 7.5% of the flour in date bars with no negative effects on sensory quality (Kamel and Kramer, 1978), and a study on the effects of torula yeast addition on the sensory acceptability of foods for hospital patients showed that yeast was highly acceptable in soups, meatloaves, casseroles, gravies, and tomato sauces. Mashed potatoes were actually found to be more accceptable upon SCP addition (Klapka, Duby, and Paucek, 1958). A dried torula yeast product, Provesteen-T, has recently been developed as a human food. The purpose of this research is to study the nutritional and organoleptic effects of adding Provesteen-T to a fried potato product. Fried potato products, though low in protein, are eaten by almost every segment of the population and have a great potential for nutrient fortification. The acceptability of a potato snack supplemented with K. fragilis has already been demonstrated (Dieken, 1976). This research will investigate the acceptability and nutritional value of incorporation of Provesteen-T in a deep fried potato product.

Materials and Methods

Preparation of Potato Product

The basic ingredients for the product, called Protato Puffs, were dehydrated potato flakes, instant starch, salt, the Provesteen-T dried yeast, and water. The ingredients were weighed and mixed together. The dry ingredients had a combined weight of 38 g. The water was brought to a boil and poured over the dry ingredients. The mixture was stirred just until all the ingredients were moistened. It was then covered and allowed to hydrate for approximately 5 minutes. After a short kneading, the mixture had a stiff, almost dough-like appearance. It was rolled out using a dough roller between 2 pieces of waxed paper to a thickness of 1.3 cm. Potato puffs were then cut out using a 1-inch round cutter. One batch made between 14 to 18 puffs depending on the water level used. The uncooked puffs were sealed in plastic storage bags and stored at $-5^{\circ}C$.

Protato Puffs were made at 4 water levels (75, 85, 95, and 105 ml) and 4 yeast levels (5, 7.5, 10, and 12.5% substitution for the dry potato weight). This gave 16 Protato Puff variations to be tested by the sensory evaluation panel. Variations were frozen for 24 hours before evaluation by the taste panel.

Sensory Evaluation

An 8-member taste panel, ranging in age from 18 to 35 years, was selected from the Oklahoma State University student body. Panelists were screened for their ability to distinguish the 4 basic flavors (sweet, sour, bitter, salty) at an above-threshold level and a below-threshold level, as recommended by the American Society of Testing Materials (ASTM) (1968). They were also screened for ability to rank the potato product in order of increasing saltiness and their ability to rank the potato product in order of increasing moisture content. (Screening score sheets found in Appendix B.) Salt identification and moisture identification were used as criteria for screening because these would be major attributes tested in the study. The criteria for selection was a score of 60% or higher of correct responses (ASTM, 1968). A 1-day training session was given to familiarize the panelists with the score sheet to be used and flavor and textural characteristics of the product to be evaluated.

Panelists rated samples for the textural characteristics of outer crispness, moisture, denseness, and perceived oiliness. A scale of 1 to 10 was used with 5 being the optimum value for all characteristics except oiliness, for which 1 was the optimum value. Descriptor words for the extremes of each scale were used.

Flavor characteristics of saltiness, bitterness, uncooked potato flavor, and off-flavor were evaluated by the panel using a 4-point scale with 0=none, 1=slight, 2=moderate, and 3=strong. Panelists were asked to describe the off-flavor if present. Overall acceptability rating for the flavor, texture, and product as a whole was also given. A scale of 1 to 10 was again used for overall acceptability ratings with 1 being "not acceptable" and 10 being "very acceptable." (Score sheets used in sensory evaluation found in Appendix C.)

The design of the experiment for this study was a randomized block design with factorial arrangement of treatments, sixteen product variations (4 levels of water and 4 levels of yeast SCP), and 3 replications. Product variations were randomized for each replication. Sessions were held on Wednesday of each week, between 2:00 and 4:00 p.m., for 6 weeks.

Samples were fried from the frozen state at 375°F. for 1 minute 45 seconds and allowed to cool for approximately 1 minute before being presented to the panelists. Panelists sat in booths separated by dividers in a normally lighted room separate from the food preparation area. They were provided with white bread and water to clear their mouths between samples. Analysis of variance (AOV) and Duncan's Multiple Range Test (Duncan, 1955) were used to determine significant differences in mean response ratings.

Fat Analysis

A factorial experiment with 16 product variations (4 levels of yeast SCP and 4 levels of water) was used to determine if there were any differences between treatment combinations in oil absorption. Five samples from each of the product variations were fried and the fat extracted. Fat content of fried samples for each yeast/water combination was determined by extraction of the whole puff for 24 hours using Soxhlet Extraction. Analysis of variance and Duncan's Multiple Range Test were used to determine significant differences in mean oil absorption.

Nutrient Analysis

Nutrient analysis of the product made without yeast and with yeast at the various levels was determined using published information on the nutrient contents of the ingredients and nutrient information supplied by the Provesta Corporation for the Provesteen-T yeast product (Watt and Merrill, 1963). (Nutrient information on Provesteen-T found in Appendix A.)

Statistical Analysis

Sensory evaluation data were subjected to an F-test from the AOV. Significant differences ($P<0.05$) between mean sensory ratings for characteristics of samples were analysed using Duncan's Multiple Range Test. Fat analysis data were subjected to an F-test from the AOV to determine if there were any treatment differences that affected fat content. Duncan's Multiple Range ($P<0.05$) was used to identify where these differences occurred.

Results and Discussion

Sensory Analysis

Analysis of variance showed there was no water/yeast interaction except for the texture characteristic of crispness. This interaction occurred at the 7.5% yeast/95 ml water level and at the 10% yeast/105 ml water level (Figure 2).

The mean values for the sensory characteristics without water/yeast interaction and the presence of significant differences between these values for the products at the various water and yeast levels are shown in Tables I through VI.

The mean values for overall texture, flavor, and product acceptability at the various water levels show a pattern of increasing acceptability with increasing water level (Table I). Water levels of 85, 95, and 105 ml gave significantly higher ratings than 75 ml but were not significantly different from each other.

The mean ratings for the texture characteristics (Table II) show no significant difference in density with increasing water level and a slightly decreased perception of oiliness at water levels above 75 ml. Optimum moisture ratings were given at the 85 and 95 ml water levels.

The flavor characteristic of saltiness was perceived as "slight" to "moderate," with no significant difference due to water level. Uncooked potato flavor received a mean rating indicating almost no presence of this flavor at any of the water levels. Mean ratings for bitter and off-flavor were between 0 (none) and 1 (slight), and both had ratings at the 95 and 105 ml water levels that were significantly lower

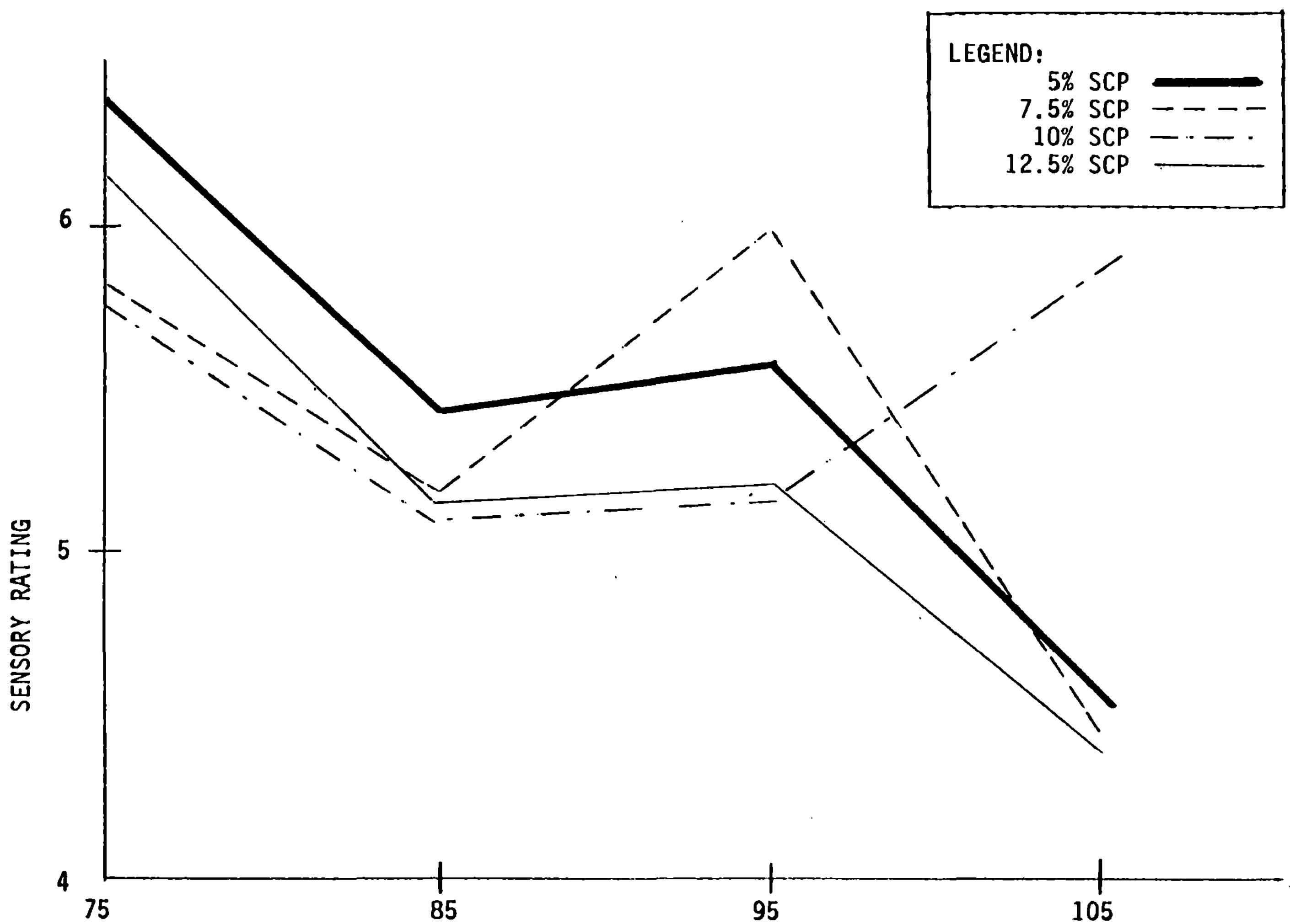

Figure 2. Water/Yeast SCP Interaction Affecting the Sensory Evaluation Ratings for the Characteristic of Crispness

than the rating at the 75 ml level (Table III). This may have been due to the dilution effect of increased water and could have contributed to the higher overall flavor acceptability and product acceptability ratings received at these water levels.

The mean values for overall texture, flavor, and product acceptability at the various yeast levels have a pattern of decreasing acceptability with increasing yeast (Table IV). Overall texture and flavor acceptability ratings at the 5, 7.5, and 10% yeast levels were not significantly different, however. Mean ratings for overall flavor acceptability at these 3 SCP levels were significantly greater than mean ratings perceived at the 12.5% level. The 5 and 7.5% levels received significantly higher ratings for overall texture acceptability than the 12.5% yeast level, and the 10% yeast level was neither significantly lower than the 5 and 7.5% yeast levels nor significantly higher than the 12.5% yeast level.

Texture characteristics of moisture and density did not change significantly with increasing yeast level. Oiliness was perceived as significantly lower at the 10% yeast level than at the 12.5% level (Table V). Although the 5 and 7.5% yeast levels were not significantly different from the 12.5% yeast level, they were also not significantly different from the 10% yeast level.

The flavor characteristic of saltiness was rated as "slight" to "moderate," with no significant change due to yeast level. Bitter flavor, uncooked potato flavor, and off-flavor tended to increase with increasing yeast level, although none were perceived to any great extent with mean ratings of between 0 (none) and 1 (slight). Significant increases in flavor perception occurred between the 5 and 12.5% yeast levels for bitter and uncooked potato flavor. Off-flavor was perceived to a significantly greater extent at the 12.5% yeast level than at the 5 and 7.5% levels (Table VI). These increased perceptions of negative flavors with increasing SCP levels may have contributed to the decreased flavor acceptability and overall product acceptability ratings received with increasing yeast levels.

All acceptability ratings for texture, flavor, and the product as a whole had values between 5 and 7. A rating of 5 or greater was considered as "acceptable" in this experiment.

Fat Analysis

An F-test from the analysis of variance showed that there was no interaction between water and yeast and also showed that there was no significant effect of water level on oil absorption (Table VII). The effect of yeast level on oil absorption was significant, and these differences are shown in Table VIII using Duncan's Multiple Range. Significant ($P<0.05$) decreases in oil absorption occurred between the 5 and the 12.5% yeast levels. An average decrease in oil absorption of 10% occurred between the 5 and the 7.5% yeast levels, 31% between the 5 and the 10% yeast levels, and 40% between the 5 and the 12.5% yeast levels.

Nutrient Composition

An increase in protein, calcium, phosphorous, iron, potassium, thiamin, riboflavin, and niacin occurs with substitution of torula yeast SCP for dehydrated potato (Appendix D). This increase becomes important (50% increase) for phosphorous, iron, riboflavin, and niacin at the 7.5%

yeast SCP level with phosphorous and iron increasing at least 100% and riboflavin increasing 200%. At the 12.5% yeast level, protein is also increased with niacin increasing 100% and phosphorous, iron, and riboflavin increasing more than 200%.

Conclusions

The effects of water level on the acceptability of this potato product appear to be minimal, although the lowest water level did receive less acceptable ratings. Also, a trend of decreasing acceptability in the texture, flavor, and total product was seen with increasing yeast levels. However, all products received ratings in these areas above 5, which would indicate an acceptable product.

The potato product substituted with 7.5% yeast was the highest level possible without getting a significant decrease in overall product acceptability rating. Other factors must be considered before a recommendation of the highest yeast level for maximum acceptability can be made. The oil absorption decreased (30%) between the 7.5 and the 12.5% yeast level. This feature, plus the fact that the nutrient content of the potato puffs increased to a greater extent at the 12.5% yeast level, make this higher substitution level the level of choice, especially since the panel rated this product "acceptable."

The feasibility of fortifying fried potato products with high levels of SCP as torula yeast and maintaining their acceptability has been clearly demonstrated in this study. The benefit of increased nutrient content with torula yeast addition, and the finding of decreased oil absorption upon frying of this product when yeast is added, indicate great possibilities for improving the overall nutritional value of a food product eaten by people of all ages in this country.

TABLE I

MEAN SCORES FOR OVERALL ACCEPTABILITY RATINGS AND SIGNIFICANT DIFFERENCES RELATED TO WATER LEVEL

CHARACTERISTIC	WATER LEVEL (ml) 75	85	95	105
OVERALL TEXTURE ACCEPTABILITY[a] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	5.62[b]	6.35[c]	6.29[c]	6.17[c]
OVERALL FLAVOR ACCEPTABILITY (NOT ACCEPTABLE TO VERY ACCEPTABLE)	5.45[b]	6.06[c]	6.29[c]	6.14[c]
OVERALL PRODUCT ACCEPTABILITY (NOT ACCEPTABLE TO VERY ACCEPTABLE)	5.56[b]	6.15[c]	6.14[c]	6.24[c]

[a]All overall acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

[b-c]Means on the same line followed by different letters are significantly different.

TABLE II

MEAN SCORES FOR TEXTURE CHARACTERISTICS AND SIGNIFICANT DIFFERENCES RELATED TO WATER LEVEL

CHARACTERISTIC	WATER LEVEL (ml)			
	75	85	95	105
TEXTURE CHARACTERISTICS[a]:				
MOISTURE (TOO DRY TO TOO MOIST)	5.57[b]	5.12[c]	5.10[c]	5.62[b]
DENSITY (NOT COMPACT TO VERY COMPACT)	4.78[b]	5.16[b]	5.11[b]	4.76[b]
PERCEIVED OILINESS (NO OILINESS TO MUCH OILINESS)	5.06[b]	4.39[c]	4.47[c]	4.59[c]
OVERALL TEXTURE ACCEPTABILITY[d] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	5.62[c]	6.35[c]	6.29[c]	6.17[c]

[a]Texture characteristics rated on a scale of 1 to 10 with 5 being the optimum value (except for perceived oiliness where 1 is the optimum value).

[b-c]Means on the same line followed by different letters are significantly different.

[d]Overall texture acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

TABLE III

MEAN SCORES FOR FLAVOR CHARACTERISTICS AND SIGNIFICANT DIFFERENCES RELATED TO WATER LEVEL

CHARACTERISTIC	WATER LEVEL (ml)			
	75	85	95	105
FLAVOR CHARACTERISTICS[a]:				
SALTINESS	1.35[b]	1.33[b]	1.29[b]	1.18[b]
BITTER FLAVOR	0.39[b]	0.25[bc]	0.20[c]	0.22[c]
UNCOOKED POTATO FLAVOR	0.15[b]	0.20[b]	0.19[b]	0.19[b]
OFF-FLAVOR	0.62[b]	0.44[bc]	0.29[c]	0.30[c]
OVERALL FLAVOR ACCEPTABILITY[d] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	5.45[b]	6.06[c]	6.29[c]	6.14[c]

[a]Flavor characteristics rated on a 4 point scale:
0=none 1=slight 2=moderate 3=strong

[b-c]Means on the same line followed by different letters are significantly different.

[d]Overall flavor acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

TABLE IV

MEAN SCORES FOR OVERALL ACCEPTABILITY RATINGS AND SIGNIFICANT DIFFERENCES RELATED TO YEAST LEVEL

CHARACTERISTIC	YEAST LEVEL (%)			
	5	7.5	10	12.5
OVERALL TEXTURE ACCEPTABILITY[a] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	6.48[b]	6.31[b]	6.00[bc]	5.63[c]
OVERALL FLAVOR ACCEPTABILITY (NOT ACCEPTABLE TO VERY ACCEPTABLE)	6.42[b]	6.20[b]	6.03[b]	5.28[c]
OVERALL PRODUCT ACCEPTABILITY (NOT ACCEPTABLE TO VERY ACCEPTABLE)	6.42[b]	6.31[b]	5.86[c]	5.50[c]

[a]All overall acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

[b-c]Means on the same line followed by different letters are significantly different.

TABLE V

MEAN SCORES FOR TEXTURE CHARACTERISTICS AND SIGNIFICANT DIFFERENCES RELATED TO YEAST LEVEL

CHARACTERISTIC	YEAST LEVEL (%)			
	5	7.5	10	12.5
TEXTURE CHARACTERISTICS[a]:				
MOISTURE (TOO DRY TO TOO MOIST)	5.39[b]	5.31[b]	5.29[b]	5.42[b]
DENSITY (NOT COMPACT TO VERY COMPACT)	4.90[b]	4.92[b]	5.09[b]	4.89[b]
PERCEIVED OILINESS (NO OILINESS TO MUCH OILINESS)	4.59[bc]	4.55[bc]	4.36[b]	5.00[c]
OVERALL TEXTURE ACCEPTABILITY[d] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	6.48[b]	6.31[b]	6.00[bc]	5.63[c]

[a]Texture characteristics rated on a scale of 1 to 10 with 5 being the optimum value (except for perceived oiliness where 1 is the optimum value).

[b-c]Means on the same line followed by different letters are significantly different.

[d]Overall texture acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

TABLE VI

MEAN SCORES FOR FLAVOR CHARACTERISTICS AND SIGNIFICANT DIFFERENCES RELATED TO YEAST LEVEL

CHARACTERISTIC	YEAST LEVEL (%)			
	5	7.5	10	12.5
FLAVOR CHARACTERISTICS[a]:				
SALTINESS	1.32[b]	1.25[b]	1.32[b]	1.25[b]
BITTER FLAVOR	0.15[b]	0.24[bc]	0.29[bc]	0.40[c]
UNCOOKED POTATO FLAVOR	0.11[b]	0.19[bc]	0.16[bc]	0.28[c]
OFF-FLAVOR	0.33[b]	0.28[b]	0.45[bc]	0.59[c]
OVERALL FLAVOR ACCEPTABILITY[d] (NOT ACCEPTABLE TO VERY ACCEPTABLE)	6.42[b]	6.20[b]	6.03[b]	5.28[c]

[a]Flavor characteristics rated on a 4 point scale:
0=none 1=slight 2=moderate 3=strong

[b-c]Means on the same line followed by different letters are significantly different.

[d]Overall flavor acceptability rated on a scale of 1 to 10 with 10 being the optimum value.

TABLE VII

ANALYSIS OF VARIANCE FOR FAT ANALYSIS DATA

SOURCE OF VARIATION	d.f.	SS	MS	F
TOTAL	79	7.97		
TREATMENT	15	4.10	0.27	4.43*
YEAST	3	2.8	0.93	15.25**
WATER	3	0.4	0.13	2.13
WATER/YEAST	9	0.9	0.10	1.64
ERROR	64	3.87	0.06	

*Significantly different at .05

**Significantly different at .01

TABLE VIII

MEAN OIL ABSORPTION PER PUFF AND SIGNIFICANT DIFFERENCES AT THE FOUR YEAST SCP SUBSTITUTION LEVELS

YEAST SCP LEVEL (%)	MEAN OIL APSORPTION (g)
5	1.17^{a}
7.5	1.05^{ab}
10.0	0.81^{ab}
12.5	0.70^{b}

[a-b]Means followed by different letters are significantly different.

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CHAPTER IV

HYPOTHESES TESTING, SUMMARY, AND RECOMMENDATIONS

The purpose of this research was to determine the effects of addition of torula yeast single cell protein (SCP) on the sensory and nutrient attributes of a fried potato product. The independant variables of the study were the potato products made with the four yeast SCP substitution levels and the four water levels. The response variables were the sensory evaluations of the product and the fat absorption of the products upon frying. The subjective (sensory evaluation) data and the objective (fat analysis) data were analysed using analysis of variance prodecures and Duncan's Multiple Range Test with a significance level of $P<0.05$.

Hypotheses Testing and Summary

The first hypothesis (H1) stated that there would be no significant differences in mean response values for selected sensory characteristics of moisture, crispness, denseness, oiliness, saltiness, bitterness, uncooked potato flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability due to water level and yeast level interaction. Statistical analysis showed that there was a significant difference in mean response values due to water level and yeast level interaction for the sensory characteristic of crispness. On the basis of this evidence, the researcher rejected H1 for the sensory characteristic of crispness. Statistical analysis did not show significant differences in mean response values due to water level and yeast level interaction for any of the other sensory characteristics, so the researcher did not reject H1 for any of these remaining sensory characteristics.

The second hypthesis (H2) stated that there should be no significant difference in mean response values given for the potato products made with the various yeast levels for the aforementioned sensory characteristics. Statistical analysis showed that significant decreases in mean response values given for the potato products made at increasing yeast levels did exist for sensory characteristics of oil absorption, bitter flavor, uncooked potato flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability. On the basis of this evidence, the researcher rejected H2 for these sensory characteristics. For the remaining sensory characteristics of moisture, denseness, crispness, and saltiness, the researcher did not reject H2.

The third hypothesis (H3) stated that there would be no significant difference in mean response values given for the potato products made with the various water levels for the aforementioned sensory characteristics. Statistical analysis showed that significant increases in mean response values given for the potato products made with increasing water levels did exist for sensory characteristics of moisture, oil absorption, bitter flavor, off-flavor, overall texture acceptability, overall flavor acceptability, and overall product acceptability. On the basis of this evidence, the researcher rejected H3 for these sensory characteristics. For the remaining sensory characteristics of denseness, crispness, saltiness, and uncooked potato flavor, the researcher did not reject H3.

The fourth hypothesis (H4) stated that there would be no significant difference in mean oil absorption upon frying between potato products made with the various yeast SCP and water levels due to yeast SCP level and water level interaction. Statistical analysis showed there to be no yeast level and water level interaction affecting mean oil absorption. On the basis of this evidence, the researcher did not reject H4.

The fifth hypothesis (H5) stated that there would be no significant difference in mean oil absorption upon frying between the potato products made with the various yeast SCP levels. Statistical analysis showed there to be a significant decrease in oil absorption upon frying between the potato products made with 5 and 12.5 per cent yeast. Based on this evidence, the researcher rejected H5.

The sixth hypothesis (H6) stated that there would be no significant difference in mean oil absorption upon frying between the potato products made with the various water levels. Statistical analysis showed there to be no significant differences in oil absorption upon frying between potato products made with the various water levels. On the basis of this evidence, the researcher did not reject H6.

The seventh hypothesis (H7) stated that there would be no difference in nutrient content of the potato product made with and without torula yeast SCP. Nutrient composition data showed there to be increasing levels of the nutrients protein, calcium, phosphorous, iron, potassium, thiamin, riboflavin, and niacin. On the basis of this evidence, the researcher rejected H7.

Recommendations

This study showed that torula yeast SCP could be added to the potato product at a substitution level of up to 7.5 per cent before adverse effects on the overall texture and product acceptability occurred and up to 10 per cent before adverse effects on the overall flavor acceptability occurred. Ratings for overall texture, flavor, and product acceptability at the 12.5 per cent level, though significantly lower that than the 7.5 per cent level, still indicated an acceptable product. In the highly competitive market of frozen potato products, small differences in acceptability could make a big difference in consumer purchasing choices, however.

This study did not evaluate the effects of increased nutrients on consumer purchasing choices. The higher SCP additions increased the nutrient content of the potato product, which might influence the consumer to purchase this product over another, even if there was a slight decrease in acceptability. The added benefit of having decreased oil absorption with increasing yeast addition, meaning fewer calories, might allow even greater addition of yeast SCP than would have been possible without these benefits. Research into this area should be done to fully evaluate the level of yeast addition possible while maintaining consumer acceptability.

There are methods of decreasing the oil absorption of potato products presently in practice. The effectiveness of yeast addition in decreasing the amount of oil absorption and cost of ingredients to create that decrease compared to the currently used methods should be evaluated.

Institutions and food service operations are the major purchasers of frozen french fries. Such purchasers would be interested in the effects of addition of yeast in the product's ability to be stored for extended periods of time and its holding ability upon frying. Studies on this should be done.

Retail stores are the major purchasers of frozen potato products other than french fries. These products are consumed by the general public and are adapted for home use. Thus, these products are generally baked in the oven rather than fried. Potato products with yeast SCP should be tested to see how they perform when prepared in this way.

Finally, addition of yeast to potato products made with ingredients other than dehydrated potato flakes should be investigated. Methods of addition of the yeast to these products and its effect on sensory and cooking qualities of the products should be investigated.

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APPENDIXES

APPENDIX A

NUTRIENT INFORMATION ON PROVESTEEN-T

NUTRIENT COMPOSITION OF PROVESTEEN-T

Composition	Weight (%)	Vitamin Content	mg/kg	Amino Acid	Weight (%)
Protein		Biotin	0.14	Lysine	3.4
Crude	55.3	Folic acid	21.1	Arginine	2.6
True	47.0	Niacin	511	Threonine	2.4
		Pantothenic acid	194	Glutamic acid	8.4
Ash	11.4	Pyridoxine	56.1	Glycine	2.3
Lipids	4.6	Vitamin B-12	0.003	Valine	2.8
Carbohydrates	22.5	Thiamine	8.7	Leucine	3.6
		p-Aminobenzoic acid	51.9	Isoleucine	2.4
Mineral Content		Riboflavin	50.5	Tyrosine	1.6
		Choline	3820	Histidine	1.0
Calcium	0.07	Inositol	2980	Aspartic acid	4.4
Magnesium	0.35			Serine	2.3
Phosphorus	3.70			Proline	1.8
Potassium	1.80			Alanine	3.3
Sodium	0.02			Methionine	0.6
	PPM			Phenylalanine	2.1
Iron	271			Cystine	0.2
Copper	36			Tryptophan	0.5
Zinc	203				
Manganese	19				

APPENDIX B

PANEL SCREENING SCORE SHEET

Panelist ________

Screening Tests

I. Identify the flavors in the following series of samples: (sweet, sour, bitter, salty)

	Sample			
Series	1	2	3	4
1				
2				

II. Rank the following series of samples in order of increasing saltiness:

	Saltiness				
Series	1(least)	2	3	4	5(most)
1					

III. Rank the following series of samples in order of increasing moisture:

	Moisture				
Series	1(least)	2	3	4	5(most)
1					
2					

APPENDIX C

POTATO PRODUCT SENSORY EVALUATION SCORE SHEET

SAMPLE ________

Rate the sample for the intensity of the following characteristics. Choose a number betwen 1 and 10 that represents the intensity as you perceive it.

Outer texture:	(1)	(10)	
Crispness:	No Crispness	Too Crisp	
(5=optimum)	(soft)	(hard, brittle)	________
Inner texture:	(1)	(10)	
Moisture:	Too Dry	Too Moist	
(5=optimum)			________
Denseness:	(1)	(10)	
(5=optimum)	Not Compact	Very Compact	
	(no bite, mushy)	(too dense, hard)	________
Oil Absorption:	(1)	(10)	
(1=optimum)	No oil absorption	Much oil absorption	________

Rate overall acceptability of the <u>texture</u> of the sample:
1=Not Acceptable   10=Very Acceptable ________

Rate the sample for itensity of the following flavor characteristics using the scale shown below.

Scale: 0=none 1=slight 2=moderate 3=strong

Saltiness ________
Bitter flavor ________
Uncooked potato flavor ________
Off-flavor ________

Describe off-flavor ________________________________

Rate overall acceptability of the <u>flavor</u> of the sample:
1=Not Acceptable   10=Very Acceptable ________

Rate overall acceptability of the sample as a whole (texture and flavor): 1=Not Acceptable   10=Very Acceptable ________

APPENDIX D

NUTRIENT COMPOSITION OF POTATO PRODUCT

NUTRIENT CONTENT OF ONE SERVING OF THE POTATO PRODUCT
WITH AND WITHOUT TORULA YEAST SCP
(1 SERVING = 10 POTATO PUFFS)

NUTRIENT	TORULA YEAST SCP (%)		
	0	7.5	12.5
ENERGY (Calories)	83.8	83.4	83.6
PROTEIN (g)	1.7	2.3	2.9*
CARBOHYDRATE (g)	19.4	18.3	17.8
CALCIUM (mg)	8.1	8.6	9.2
IRON (mg)	0.4	0.8**	1.2***
SODIUM (mg)	18.5	17.4	16.9
POTASSIUM (mg)	369.6	372.8	379.4
VITAMIN C (mg)	7.4	6.9	6.5
THIAMIN	0.05	0.06	0.07
RIBOFLAVIN (mg)	0.01	0.10***	0.16***
NIACIN (mg)	1.2	2.0*	2.6**

*50% increase over the product containing 0% torula yeast SCP

**100% increase over the product containing 0% torula yeast SCP

***200% increase over the product containing 0% torula yeast SCP

VITA

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Candidate for the Degree of

Master of Science

Thesis: EFFECTS OF ADDITION OF TORULA YEAST SINGLE CELL PROTEIN ON THE SENSORY AND NUTRIENT QUALITIES OF A FRIED POTATO PRODUCT

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